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Use of Farmers' Indicators to Evaluate the Sustainability of Cropping Systems on Sloping Land in Yunnan Province, China[*1]

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ABSTRACT

Diversity in the biophysical and socio-economic attributes of agricultural systems makes them uniquely niche based. Farmers are expert in local biophysical and socio-economic situations and can contribute in developing pragmatic indicators of agro-environmental development. During evaluation of an agricultural research project in Yunnan, China, local farmers were capable of evaluating the effects of modified technologies on existing cropping systems and discussed their attitudes to the interventions using their own indicators. Farmers' response can be grouped into seven major aspects: i) effects on income, ii) effects on production resources, iii) effects on crop management, iv) existing local knowledge about the technology, v) availability of inputs, vi) access to information, and vii) socio-economic conditions of farming households. Farmers concluded that environmental conditions in the experimental catchment in comparison to an adjacent untreated catchment were better in terms of soil and water losses, vegetation cover and natural resources, infrastructures and catchment management, use of environmentally-friendly technologies, and crop productivity. Success in soil and water conservation programmes depends on the efforts of the farmers and other local users and their greater involvement helps to identify more pragmatic indicators. Furthermore, it increases ownership of the programme, enhances interactions with the project scientists, increases farmers' awareness of agro-environmental problems and their possible consequences. These development will enable scientists to develop better targeted interventions and increase the likelihood of adoption of tested technologies by local communities. The use of paired adjacent catchments improved evaluation activities and is proposed as good practice for future catchment improvement programmes.

Key Words: agro-environmental sustainability, China, farmers' evaluation, farmers' indicator, paired catchments

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INTRODUCTION

Until the 1970s, the emphasis in agriculture was on achieving higher agricultural productivity, with little regard to sustainability (Brady, 1990; Pretty, 1995). Consequently, production systems in most parts of the world witnessed various problems associated with land degradation, soil erosion, water pollution and resource depletion (Lal *et al.*, 1988; Pratap and Watson, 1994; Evans, 1998; Hurni, 2000; Röling, 2005), making the sustainability of current agricultural systems doubtful (Rigby *et al.*, 2001). Therefore, there was increasing awareness of the need for more sustainable, environmentally-friendly cropping practices (UN, 1992). This led to increased efforts by various organizations at local to global scales to define, measure and achieve sustainability. Sustainability indicators have been developed and different frameworks have been proposed to organize the indicators and measure sustainability more

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systematically.

Different organizations and authors have produced different definitions of sustainable development and sustainable agriculture. Despite the variation in the wording, the central theme contained in most definitions is on improving or maintaining output while maintaining or enhancing the quality and regenerative potential of natural resources.

Indicators are datasets that provide a simple and reliable basis for measuring change or performance. The indicators quantify change, identify processes and provide a framework for setting targets and monitoring performance (Crabtree and Bayfield, 1998). Indicators provide information about current status, progress trends, pressure points, effect of interventions, areas requiring attention and milestones, whether achieved or not. Agricultural sustainability, by nature, is a long term, complex and multi-faceted issue (Gorrie, 1999). The three dimensions (the environmental, social and economic) of sustainability dynamically interact with each other, thus a balance is needed to maintain these three components in equilibrium (Tschirley, 1996). So any programme aimed at sustainable agricultural development requires careful selection of indicators to measure the successes made in different components of the system and cross-cutting issues over time. Carefully selected and effectively used indicators can indicate changes and flag important conditions and trends that can help in development planning and decision-making (Tschirley, 1997). However, indicators selected without due care may provoke disagreement and debate among stakeholders. Work in partnership with farmers helps in solving the identified problems and achieving sustainable improvements (Shaxson, 1997).

Farmers have their own traditional methods to evaluate and/or assess systems. Farmers use indigenous indicators for determining decreased soil erosion (Benites *et al.*, 1997). Similarly, a Costa Rican farmer used soil compactness as the basis to judge the effectiveness of an on-going project, while a farmer in India observed that decreased porosity resulting in decreased water infiltration into the ground is the reason for increased incidence of local floods (Shaxson, 1997). Farmers use these indicators of change in their own words and may not use the technical terms, for example instead of the word 'compactness' farmers used the word 'fluffy' (Shaxson, 1997). Some efforts have been made to identify and report farmers' indicators, however few attempts have been made to capitalize on farmers' wisdom in developing indicators and frameworks. At least verifying some of the indicators, if not all, would help identify the most relevant sets of indicators and the development of more robust frameworks.

Agricultural sustainability itself is a broad issue and comprises several interacting aspects, including the socio-economic situation of farming communities. Diversity in biophysical and socio-economic aspects of agricultural systems makes agricultural systems uniquely niche based (Hudson, 1991) and makes it difficult to develop one set of indicators suitable for all environmental and socio-economic conditions. Local farmers know more about these aspects than external experts. So their participation helps in developing and/or selecting more pragmatic indicators.

The objective of this work was to study farmers' indicators which were developed for use in evaluating project technologies and development activities. The magnitude of the effects of agricultural interventions at household level was likely to vary among households due to variations in factors affecting farming practice, such as economic status, input use and labour availability. So, a household survey (HS) was used to study the effect of project interventions which were likely to impact on the socio-economic conditions of farming households. The PRA (participatory rural appraisal) workshop was carried out to study farmers' perceptions of the effectiveness of the project in improving agro-environmental conditions within the catchment. This was achieved by examining and comparing the agro-environmental situation within Wang Jia (project catchment) and Lai Zi (an adjacent catchment outside the project area).

MATERIALS AND METHODS

This paper is based on experiences of evaluating the European Union SHASEA (Sustainable High-Land Agriculture for South-East Asia) Project, which was implemented in Wang Jia Catchment of

Kelang Village in Yunnan Province, China. Participatory evaluation was conducted on completion of the project, to study the effectiveness of project technologies and the likelihood of their future adoption/adaption. In addition, a 'farmers' workshop' was organized to study the effect of project activities on the agro-environment of the project catchment, by comparing it with the adjacent Lai Zi Catchment outside the project area (Fig. 1). The comparison and evaluation were carried out on the basis of farmers' criteria/indicators.

Fig. 1 Wang Jia (left) and Lai Zi (right) Catchments in Yunnan Province, China.

Wang Jia and Lai Zi are two adjacent catchments of Kelang Village within Kedu Township in Xun Dian County, North-east Yunnan. Wang Jia Catchment is situated at latitude 25° 28′ N and longitude 102° 53′ E. The catchment altitude ranges between 2 044–2 191 m a.s.l. The total catchment area is 40.1 ha, of which 27.3 ha of sloping uplands is suitable for cultivation, 1.1 ha is covered by sweet chestnut trees, 0.4 ha by rocky land, 9.5 ha by forest trees and 1.8 ha by barren hills (Fullen *et al.*, 2001). The local climate falls under the sub-tropical monsoon climate zone, with a mean annual rainfall of 1 043 mm. The distribution of rainfall is uneven. Most (some 80%) rain falls between June and October, with a dry period between November and May (a period of moisture stress for winter crops). Lai Zi Catchment is situated close to Wang Jia Catchment and they are separated by a deep gorge of a small highland stream. The altitude of Lai Zi Catchment is similar to Wang Jia Catchment. Being an adjacent catchment, climatic parameters can be considered similar to Wang Jia.

Extracting the views of local stakeholders, particularly farmers, is challenging in China, mainly due to difficulties in communication and the socio-political situation. Therefore, it was necessary to verify the information collected from one source with other sources. So, a multi-approach participatory evaluation study was designed, of which household survey and PRA techniques (group discussions and farmers' workshops) were used in this study.

Household survey

A questionnaire survey was administered to 63 (41.4%) of the 152 farming households in the project area. Cropping practices developed and tested at a research station were applied first to research plots in the catchment managed by the project team, to carry out technical evaluations under field conditions. Practices that appeared to be effective were introduced to farmer-managed observation plots throughout the catchment, following a series of field training workshops led by the Chinese partners. Sixty-three farming households owned the farmer-managed observation plots in the catchment, so they were interviewed. The household head or the person responsible for farming was interviewed, so the choice of male or female farmers for interview was dictated by their position in the family or role in farming activities. Before launching the survey, a questionnaire was prepared and translated into Chinese. The questions and data collection methods were also discussed in detail with enumerators, who gave their critical appraisal of the questionnaire, to assist its optimization. Then practice surveys were conducted by interviewing farmers who were not actual respondents of the study.

Participatory rural appraisal (PRA)

The participatory group approaches were used to evaluate SHASEA Project activities and outcomes at a broader (community/catchment) level. The effects of project interventions on agricultural production and environmental conditions in the catchment and the socio-economic conditions of farmers were discussed. PRA methods, such as group discussions, transect walks, farmers' workshops and field observations, were conducted with the active participation of farmers.

A checklist was prepared for group discussions. Farmers from across the wealth and gender categories were involved in the exercise. Farmers' workshop was completed in three stages: i) farmers were requested to develop their own criteria/indicators for the examination, evaluation and comparison of the catchments; ii) farmers were then requested to examine and compare the environmental conditions of the two catchments based on these criteria, and a transect walk was organized so that farmers had the opportunity to closely examine both catchments; and iii) a group session completed the evaluation process. The conditions of the two catchments were described, evaluated and compared based on rigorous discussion of each criterion.

RESULTS

Farmers' indicators for technology evaluation

The advantages/disadvantages, strengths/weaknesses and attitudes to agricultural interventions were discussed with farmers during household survey and PRA group discussion. During discussions, farmers mentioned the reasons for their attitudes to any particular technology using their own indicators. Farmers' indicators have been abstracted from various discussions. Farmers' indicators focused on the selected aspects for the selection or rejection of the agricultural technologies (Table I).

Farmers generally gave priority to the overall increase in crop production and associated increased income for the selection or rejection of any agricultural interventions. They used different indicators to evaluate the effect on production and income, such as changed crop yield and changed income/profit. In addition to these directly measurable indicators, farmers also used some indicators which were more causative in nature, such as adverse effects on the main crop, competition between crops and shading effects on crops.

Farmers were equally concerned about the effect of new interventions on production resources. Farmers considered indicators, such as conservation/losses of soil, water and soil fertility, changed soil properties (soil organic matter and moisture content), changed soil properties and changes in crop performance, for the selection and rejection of agricultural technologies. Farmers also used symptomatic indicators, such as less fertilizers required, better seedling emergence, better crop growth, earlier crop maturity and looser soil, to articulate the effect of agricultural interventions on production resources.

Farmers also selected or rejected agricultural technologies based on the effects of technologies on crop management. Labour requirements, ease of farming operations, convenience of using technology (such as mulching under intercropping conditions and using irrigation on steep slopes and distant plots) and undesirable effects from technology (such as disease/insect spread from straw/trees and emergence seed present in the straw and acting as weed) were the major management related indicators used by farmers. Labour requirements are directly related to production costs and hence profitability of farm output. Similarly, ease of management is associated with labour requirements. Thus, reduced labour requirements and production costs seem important parameters for any technologies to be successful in terms of farmers' adoption.

Farmers were sceptical about adopting technologies which were not traditionally used under their own farming conditions. Farmers often reported 'not used traditionally' or 'not a traditional practise' as one of the reasons for not adopting the technology. This could be because farmers want to be assured

TABLE I

Ranking of farmers' indicators for selecting/rejecting different soil conservation and crop improvement technologies using results from household survey (HS) and participatory rural appraisal (PRA), Kelang, Summer 2002 and 2003

For selection	HS[a]	PRA[b]	For rejection	HS	PRA
Contour cultivation system					
Soil, water and nutrient conservation	85	1	Difficult to implement	NA[c]	1
Increase crop production/income	34	2	More weed problems, difficult to earth up and requires more labour	NA	2
Ease of crop management/save labour	7	3	Water stagnation: not good for crops susceptible to damage by excess water	NA	3
Downslope cultivation system					
Ease of management (earthing-up, cover polythene, drain water, weed control and tillage)	NA	1	Increased losses of soil and water	NA	1
Save labour	NA	2	Low water availability to crops	NA	2
Easy for intercropping	NA	3	Losses of soil fertility	NA	3
Straw mulch					
Conserve soil, water and fertility	NA	1	Straw not available	51	1
Increase organic matter in soil	NA	2	Difficulty in crop management and requires more labour	49	2=[d]
Soil becomes loose	NA	3	Disease/insect spread from straw	NA	2=
			Not used traditionally/no information	40	NA
Polythene mulch					
Increase production/income	70	1	Requires more labour	43	1=
Conserve soil and water	67	2	Lack of money	6	1=
Conserve soil fertility/requires less fertilizers/crops grow better	10	3	Adverse effect to succeeding crops if polythene is not removed	NA	2
Easy and effective to control weeds	NA	4	Not used traditionally	25	NA
Easy for crop management/saves labour	11	5=	Polythene not available	10	NA
Increase soil temperatures, crop grows faster and matures earlier	8	5=			
Intercropping					
Increase production/income	51	1	Adverse effect to main crop/competition/ production decrease	18	1
Good effect on soil by legume crop	11	2=	Crop management, mainly weed control, is difficult	8	2
Better land utilization	8	2=	Lack of labour	2	3
Conserves soil and water	5	4	Low economic benefit	2	4
Tree planting (Agro-forestry)					
Increases income	42	1=	Lack of land	25	1
Conserves soil and water	11	1=	Lower income than crops at the beginning/ unprofitable	8	2=
Available for household consumption	11	NA	Lack of labour/resources	6	NA
Poor/sloping land: not suitable for annual crop cultivation	5	NA	Shading effects on crops	NA	2=
Saves labour	4	NA	Crop management is difficult	NA	4
More trees ('greener') in the area	2	3	Disease, insects and bird problems from trees affecting crops	NA	5
Irrigation					
Security against drought	NA	1=	Irrigation not sufficient/not convenient to use	70	1
Good seedling emergence	NA	1=	Lack of labour	22	2
Increase in crop production/income	NA	3	Lack of money to buy pipes	11	NA
Possible to plant high value crops	NA	4			
Timely planting possible	NA	5			

[a] Data are percentages of responses from HS which identified the indicator for selecting or rejecting the technology.
[b] Ranking of indicator for selection or rejection of the technology from PRA.
[c] Not applicable, because either this technology was not used in the experimental catchment at the time of the household survey or there were no responses on this technology in the household survey.
[d] The rank figure with '=' sign indicates that there are more than one indicators with the same ranking position.

about the benefits and superiority of any new technology. So, farmers were seeking information on the performance of new technology under their farming conditions.

Technology adoption was strongly influenced by the timely and local availability of resources in sufficient quantities, such as fertilizers or polythene sheeting. Similarly, positive effects on input, such as saves labour, less fertilizers are required and contour cultivation makes irrigation easier and more effective, were the indicators used for technology adoption.

Farmers reported 'lack of information about technology' and 'poor knowledge about the technology' as reasons for rejecting a technology. This was also revealed by field observations, where some farmers planted trees at very high densities (up to four times higher than the recommended density), displaying their lack of awareness of recommended tree spacing.

Farmers used some socio-economic indicators to explain the reason for the selection or rejection of technologies. Farmers mentioned that improvement in the aesthetic value of the environment (more trees, more greenery) and assurance of security against natural hazards (irrigation for drought) as reasons for technology adoption. Farmers considered the suitability of their production environment to new technology and mentioned that they planted trees in poor/sloping land, which was not ideal for growing annual crops. Poor economic conditions, lack of money/cannot afford, lack of land, lack of labour and poor/unsuitable land were further reasons for farmers rejecting the technology.

Farmers' indicators for evaluation and comparison of catchments

Farmers observed, evaluated and compared the environmental condition of Wang Jia and Lai Zi catchments. Prior to this, a group of discussion (facilitated by researchers) was organized to develop their own indicators for the evaluation and comparison of catchments. The indicators were developed by farmers themselves through a process of identification, discussion and consensus building.

The indicator development exercise was conducted with the expectation that it would provide a basis for the comparison of researchers' and farmers' criteria. It would provide information on whether any parameter important for researchers was also important for farmers. It was also planned that if farmers did not mention any of the criteria identified by researchers, then the importance (or otherwise) of researchers' criteria should be discussed. The ultimate aim was to check the parity between researchers' work and farmers' understanding and perception.

Prior to the indicator development exercise of farmers, the following broad criteria were identified with a view to check whether farmers considered these broad issues: i) erosion scars (number and size of erosion scars), ii) vegetation cover (forest area, grass cover area and crop area), iii) eroded area, iv) presence of gullies (number of gullies), v) size and depth of gullies, and vi) general crop vigour (soil fertility status).

Farmers mentioned all the broad criteria identified by researchers. Farmers considered 15 different primary level indicators to compare the two catchments. However, considering the similarity among them, the 15 criteria developed by farmers have been presented under 11 criteria (Table II).

Farmers were particularly influenced by the landscape engineering that had been carried out in the project catchment. Farmers considered the conditions of gullies and check-dams, and the extent of landslides to compare soil and water losses between the catchments. Farmers concluded the condition of gullies to be better in Wang Jia because of the presence of sidewalls in the gullies, shallower depth and the presence of grasses and bushes in gullies. Check-dams were only constructed in Wang Jia, where the main gully had been rehabilitated and water and soil erosion decreased. Similarly, the number of gullies and landslides were reduced in size and number in Wang Jia.

Issues like vegetation cover and vigour and soil quality were considered. Wang Jia was reported to have better vegetation cover and vigour, with more trees and bushes, well-grown tall trees and a 'greener' appearance. Farmers perceived that soils in Wang Jia were loose with small amounts of gravel and stones, whereas in Lai Zi Catchment the soil was compacted and hard with large amounts of sand, gravel and stones. Soil depth in Lai Zi was shallow and deep tillage was not possible. Soil fertility status

TABLE II

Farmers' evaluation and comparison of Wang Jia and Lai Zi catchments, PRA Farmers' Workshop, 2002

Wang Jia Catchment	Lai Zi Catchment
Conditions of gullies and check dams	
Lack of natural sources of water	Presence of two natural water sources (natural springs)
Slopes gentler than in Lai Zi; less soil and water loss	Steeper slope; more soil water loss; landslides likely
Stones laid on the sidewalls of gullies; shallower gullies	Many large and deep gullies, few stones on the gully sides
More grasses and bushes in the gullies	Less grass and bushes on the gully sides
Situation regarding soil and water losses	
Effective soil and water conservation	No soil and water conservation effort
Use of contour cultivation	Use of downslope cultivation
Many trees planted; grass strips used	More bare land; no grass strips
Fewer gullies present; check-dams constructed	More gullies present; no check-dams
Grasses and bushes in the gullies	Less grasses in the gullies
Fewer landslides	More and larger landslides
Extent of landslides (size, number)	
Fewer and smaller landslides and gullies	More and larger landslides and gullies
Presence of grasses in and around the gully	Presence of few grasses in the gully
Construction of stone wall on the gully side	Presence of fewer stones and more soil on gully
Situation regarding vegetation (number of trees, vegetation cover)	
Good vegetation cover and vigour	Poor vegetation cover and vigour
More trees and bushes; tall trees	Fewer trees; short trees
The catchment looks 'greener'	Poor vegetation, catchment looks yellow/brown
Catchment management (control of grazing and vegetation management)	
Management is easy as the catchment is under one village	Management is difficult as catchment is under two villages
Livestock in the catchment is prohibited and grazing stopped	Catchment is not looked after; free grazing is practised
Access road to the main road constructed	Only trekking trails present in the catchment
Fodder/forage harvesting is controlled	
Deforestation controlled, vegetation is protected from fire	
Provision of staff to manage irrigation ponds	
Cultivation and cropping practice	
Improved agricultural technology used	Use of traditional farming technology
Use of contour cultivation	Downslope cultivation practised
Straw and polythene mulch used	No use of straw mulch
Greater area under intercropping systems	Less use of intercropping
Crop production and productivity	
Use of improved varieties	No use of improved varieties
Homogeneous height and thick stem of the maize crop	Heterogeneous plant height and thin/weak stems of maize crops
Managed by the project	No organized catchment management
The production of maize is expected to be high	The production of maize is expected to be low
Production of other crops is expected to be high	Low crop productivity
Steepness of sloping land	
Slope steepness is less than in Lai Zi	Slope steepness is more than in Wang Jia
Area of sloping land is less than in Lai Zi	Area of sloping land is more than in Wang Jia
Tractors can be used to till some sloping land	Steepness is great; only human and livestock can work
Soil types and quality	
Red soil, clay, loose soil	Sandy soils, stones in cropland, hard soil
Soil is deep; can be tilled deeply	Less (thin) soil depth; not possible to till deeply
Soil fertility and soil moisture are good	Poor soil fertility and soil moisture
Fewer and smaller stones present in croplands	More and large-sized stones present in croplands
Existence of water sources	
Presence of irrigation systems	No irrigation systems
Crop cover (area)	
Most area under maize, sunflower and pumpkin	Small area under maize, sunflower or pumpkin
More sweet chestnut trees	Few sweet chestnut trees
Large area under leguminous crops	Small area under leguminous crops
Small area under potato	Large area under potato
Presence of man-made grass strips	No grass strips in the catchment

was better in Wang Jia, with better soil moisture status.

Farmers considered provision of a 'caretaker' in the catchment, access road, check-dams and the irrigation system to compare the infrastructure and management efforts in the two catchments. The project support in hiring a caretaker, who was instrumental in controlling grazing, deforestation and forest encroachment in Wang Jia Catchment was much appreciated by participating farmers. In addition, farmers presented scientific approaches of conservation and use of natural resources (fodder/forage), management and use of the irrigation system and the control of hazards, such as fire, as evidence of better management in Wang Jia. These attributes were lacking in Lai Zi. An access road, check-dams and irrigation systems were only constructed in Wang Jia.

Farmers considered the use of environmentally-friendly technologies, such as contour cultivation, straw and polythene mulches, intercropping and other improved agricultural technologies, for the evaluation of the two catchments. Farmers concluded that cultivation and cropping practices in Wang Jia were better because of the improved agricultural technologies. Large areas in Lai Zi were under traditional farming systems. Farmers also perceived that the use of grass strips was one of the reasons for better environmental conditions in Wang Jia.

Farmers mentioned the cultivated area, crop vigour and estimated crop productivity to compare crop performance and productivity within the two catchments. Farmers noted the cultivated area in Wang Jia to be greater than in Lai Zi. Similarly, farmers reported that crop performance was better in Wang Jia. Maize crop height was more homogeneous and stems were thicker and more robust in Wang Jia, while performance of maize was heterogeneous with generally thinner stems and weaker plants in Lai Zi.

DISCUSSION

Farmers' indicators for technology evaluation focused on effects of technology on farm production and farming household incomes; production resources and crop management; existing local knowledge about the technology; availability and effects of inputs; access of information and the socio-economic conditions and perceptions of farming households. Increased crop production and income; conservation of soil, water and soil fertility and labour saving were the frequently cited indicators for the selection of cropping technology.

There is clear distinction between the issues surrounding sustainable agriculture on flat *versus* sloping land. Land with $\geq 35\%$ slope gradient is categorized as 'sloping land', which is vulnerable to rapid topsoil loss in response to agricultural practices (Sombatpanit, 2001). The high slope gradient favours rapid overland flow, which increases soil loss and decreases soil moisture retention. Topsoil loss usually decreases crop productivity and nutrient supply (Sajjapongse, 1992). Thus, the initiatives on sloping land focused on decreasing soil, water and nutrient losses, by reducing runoff and thereby erosion. Consequently land degradation and desertification decreased, in addition to improving fertility status and soil biological properties (Pratap and Watson, 1994; Tang, 1999; Panomataranchagul *et al.*, 2001; Fullen *et al.*, 2001). Farmers in Kelang Village also considered these issues for the evaluation of cropping technologies.

The overall responses of the farmers during catchment evaluation focused on five major aspects, *viz.*, i) current situation of soil and water losses, ii) vegetation cover and natural resources, iii) infrastructures and catchment management, iv) use of environmentally-friendly technologies and v) crop performance and productivity. Farmers found that Wang Jia Catchment was better protected. Particularly, they ascertained that the efforts to stop human abuse and animal pressure on forest resources, safeguard the environment and maintain the infrastructure were all better than in Lai Zi Catchment. The farmers also reported the problem of coordination in managing and using natural resources in the catchments, particularly where control of the resources was shared by more than one village, as in the case of Lai Zi. Moreover, they reported that deforestation and forest encroachment to bring more land under cultivation was proceeding in Lai Zi. This indicates that farmers consider protection as key to improving the natural environment. Deforestation, overgrazing, loss of soil fertility and decreased crop yield are major indicators of land degradation (Shi and Li, 1999). Wang Jia benefited from infrastructure development, particularly the access road, irrigation system and check-dams, which were lacking in Lai Zi. The farmers considered that, directly or indirectly, these infrastructures contributed to improved environmental conditions.

Several questions were posed to participating farmers: how different were the agro-environmental conditions of Wang Jia and Lai Zi catchments before project implementation? To what extent did project activities contribute to Wang Jia having better agro-environmental conditions than Lai Zi? Farmers said that the conditions in Wang Jia were slightly better than Lai Zi before project intervention. However, the magnitude of difference in the conditions of these catchments had notably increased due to project activities.

Farmers developed only primary level indicators at the beginning of the farmers' workshop (before visiting the catchments), but they considered secondary level indicators as a basis for discussing most criteria. Farmers used the same secondary level indicators to evaluate and compare more than one primary level indicator.

During the farmers' workshop, farmers mentioned all the broad criteria, which were identified by researchers prior to the indicator development exercise with farmers. This suggests that farmers' understanding accorded closely with scientific understanding. In addition, farmers developed more detailed indicators compared to researchers' indicators. They were capable of developing and using secondary (more specific) indicators to explain primary (relatively broad) indicators. This suggests that farmers of Kelang Village were highly capable of evaluating environmental changes in Wang Jia Catchment using scientific indicators and indicates their potential to work in collaborative ventures for soil conservation and catchment improvement.

Local people, particularly farmers, are the primary users of natural agro-resources. Therefore, the availability and use of these resources will be strongly influenced by their decision-making processes, leading to positive or negative impacts on system sustainability (Wattenbach and Friedrich, 1997). Environmental conservation (including cropping system improvement and soil and water conservation) issues are multi-faceted, where different actors are involved in diverse ways. Therefore, success in environmental conservation programmes depends on the efforts of these stakeholders, primarily farmers and local users. Farmers' involvement in such programmes helps to identify useful, appropriate and pragmatic indicators and increases their ownership of the programme. Such collaborative activities increase the interaction between scientists and farmers/local users, which increases farmers' awareness about agro-environmental problems and their possible consequences. Collaboration also increases the capacity of scientists to develop more targeted programmes, from both technical and socio-economic perspectives. Inclusion of farmers' indicators in scientific evaluations would increase the likelihood of farmers' adoption of proposed technologies.

Farmers in developing countries are generally poor and deprived of even basic goods and services, so maintaining or improving livelihoods is their prime objective for any change in their farming system (Wattenbach and Friedrich, 1997). They analyse the possible effect of any advice or option on their livelihood strategy and give less preference to changes which do not have clear benefits for their standard of living. The changes that affect their condition are screened through their own decision-making processes, analysing the possible effects of the change involving pragmatic indicators. This ultimately determines the adoption of such interventions (Shaxson, 1997). The importance of farmer participation is reported in goal setting (Subedi *et al.*, 2001; Jain *et al.*, 1997), natural resources management (Bhatia and Karki, 1999; Ritsema *et al.*, 2001; Evans and Sophana, 2004), technology transfer (Acton and Phien, 2001) and enhancing farmers' adoption (Howeler, 1996). In this context, participation of local farmers in research and development processes may help in identifying the most useful indicators for the adoption of agricultural technologies. Moreover, the quality of the interactions between extension staff and local people influences the impacts of soil conservation programmes (Thompson and Pretty, 1996). The impacts were substantially greater when participation in planning and implementation were interactive and interdisciplinary, rather than when participation was simply consultative. In addition, the involvement of local user groups in the monitoring and evaluation of spatial and temporal changes in the catchment can be beneficial to both local users and researchers. For local users, it may help to improve 'land literacy' (the ability to identify and appreciate good/bad conditions) about the catchment. For researchers, it would provide less expensive and rapid information about complex natural resources management issues compared to conventional approaches requiring large and expensive information sets (Ravnborg, 1996).

At present, knowledge and understanding of the links and interactions within and among different ecosystems are limited. Therefore, future research should also concentrate on studying the interdependencies within and among ecosystems, to improve understanding of the effects of incoming loads on the sustainability of entire systems (Lewandowski *et al.*, 1999). Local farmers possess more and better knowledge about local systems than outsiders. So their participation in the process can help to identify the weakness and potential of the systems and ensure identification of more pragmatic and niche-based indicators.

The indicators presented in this paper are examples of criteria based on which farmers evaluate and decide whether to adopt new technologies. In addition to scientific rigour, if these criteria are also considered for evaluations by scientists, the likelihood of farmers' adoption of proposed technologies could increase. So identification of farmers' indicators and their inclusion is suggested for future agricultural research and development programmes.

Study of a pair of adjacent similar catchments provided an opportunity to compare the effects of research and development activities in one catchment against the other catchment without any intervention. This also provided an opportunity to convince farmers and other stakeholders about the importance of such research and development activities. Thus, use of paired adjacent comparable catchments is suggested for future research and development programmes investigating catchment improvement.

CONCLUSIONS

The farmers of Kelang Village were highly capable of evaluating environmental changes in the catchments using their own traditional indicators, which were similar to scientific indicators. This indicates their potential to work in collaborative ventures for soil conservation and catchment improvement. Farmers had different perceptions about the range of cropping practices introduced and tested in the project catchment and discussed the reasons for their attitude to any particular technology using their own indicators. Farmers' response can be analysed and grouped into seven major aspects, *viz.*, i) effects of production on income, ii) effects on production resources, iii) effects on crop management, iv) existing local technological knowledge, v) availability and effects on inputs, vi) access to information, and vii) socio-economic conditions of farming households.

Similarly, during a workshop, farmers concluded that environmental conditions in Wang Jia Catchment were better than in the adjacent Lai Zi Catchment. Farmers' response can be analysed and grouped into five major aspects, *viz.*, i) current situation of soil and water losses, ii) vegetation cover and natural resources, iii) infrastructures and catchment management, iv) use of environmentally-friendly technologies, and v) crop performance and productivity.

Farmers' evaluations leading to the selection or rejection of new technologies proposed by the outcomes from agricultural research projects are based primarily on their own indicators. There is good agreement between the ranking of indicators produced by HS and PRA, with the top three indicators from PRA typically including the overwhelming majority of responses from household surveys. The use of these top three indicators in scientific evaluations by project teams would increase the likelihood of adoption of newly proposed technologies. In our study, the use and development of farmers' indicators enhanced the collaboration between farmers and scientists. Therefore it is proposed that the identification and use of farmers' indicators should be included routinely in future agricultural research and development programmes.

Furthermore, the use of paired adjacent catchments provided additional opportunities for the identification and application of farmers' indicators and may be a useful tool to enhance the evaluation and subsequent adoption of improved technologies resulting from research and development activities.

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REFERENCES

Acton, D. and Phien, T. 2001. Farmer Participatory Research and Technology Transfer on the Use and Management of Sloping Lands in Vietnam. End of Project Report. Phase 2. Canadian Society of Soil Science, Canada and Vietnamese Soil Science Society, Vietnam.

Benites, J. R., Shaxson, F. and Vieira, M. 1997. Land condition change indicators for sustainable land resources management. *In* Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development. Food and Agriculture Organization (FAO), Rome. pp. 57–75.

Bhatia, A. and Karki, S. (eds.). 1999. Participatory Forest Management: Implications for Policy and Human Resources' Development in the Hindu Kush-Himalayas. Vol. 1. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Brady, N. C. 1990. Making agriculture a sustainable industry. *In* Edwards, C. A., Lal, R., Madden, P., Miller, R. H. and House, G. (eds.) Sustainable Agricultural Systems. Soil and Water Conservation Society, Iowa. pp. 20–32.

Crabtree, B. and Bayfield, N. 1998. Developing sustainability indicators for mountain ecosystems: A case study of Cairngorms, Scotland. *J. Environ. Manag.* **52**: 1–14.

Evans, L. T. 1998. Feeding Ten Billion: Plants and Population Growth. Cambridge University Press, Cambridge.

Evans, P. T. and Sophana, V. 2004. Lessons from the 'Participatory Natural Resource Management in the Tonle Sap Region' Project. *In* Torell, M., Salamanca, A. M. and Ratner, B. D. (eds.) Wetlands Management in Cambodia: Socio-economic, Ecological, and Policy Perspectives. Technical Report 64. World Fish Center, Penang, Malaysia. pp. 27–29.

Fullen, M. A., Hocking, T. J., Mitchell, D. J., Milne, E., Wilson, M. J., Cuddy, M., Steele, S., McDonough, T., Bock, L., Dautrebande, S., Lacroix, D., Casse, C., Vinck, P., Baudoin, J. G., Van Caillie, D., Wu, B. Z., Liu, L. G., Li, Y. M., Huang, B. Z., Sun, H. Q., Chen, J. D., Wang, S. H., Liu, H. M., Wang, Y. Z., Ma, C. Y., Pu, J. L., Jin, Z. B., Ma, S. Y., Panomataranchagul, M., Sukkasem, C. and Peukari, S. 2001. Multidisciplinary approaches to soil conservation in the highlands of South China and Thailand. *In* Helming, K. (ed.) Multidisciplinary Approaches to Soil Conservation Strategies. ZALF (Zentrum für Agrarlanschafts- und Landnutzungsforschung e.V.), Müncheburg, Germany. pp. 139–145.

Gorrie, G. 1999. Sustainable Indicators in a Policy Context. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra, Australia.

Howeler, R. H. 1996. The use of farmer-participatory research methodologies to enhance the adoption of soil conservation practices in cassava-based cropping systems in Asia. *In* Sombatpanit, S., Zobisch, M. A., Sanders, D. W. and Cook, M. G. (eds.) Soil Conservation Extension: From Concepts to Adoption. Science Publishers Inc., Enfield, USA. pp. 159–168.

Hudson, N. W. 1991. A Study of the Reasons for Success or Failure of Soil Conservation Projects. FAO Soils Bulletin No. 64. Food and Agriculture Organization (FAO), Rome.

Hurni, H. 2000. Soil conservation policies and sustainable land management: A global overview. *In* Napier, T. L., Napier, S. M. and Tvrdon, J. (eds.) Soil and Water Conservation Policies and Programs: Successes and Failures. CRC Press, Boca Raton. pp. 19–30.

Jain, H. K., Singh, R. N., Dewangan, K. N. and Sharma, O. P. 1997. Farmer participation and technology adoption in India: Case studies. *In* Sombatpanit, S., Zobisch, M. A., Sanders, D. W. and Cook, M. G. (eds.) Soil Conservation Extension: From Concepts to Adoption. Science Publishers Inc., Enfield, USA. pp. 429–440.

Lal, R., Miller, F. P. and Logan, T. J. 1988. Are intensive agricultural practices environmentally and ethically sound? *J. Agr. Ethics.* **1**: 193–210.

Lewandowski, I., Hardtlein, M. and Kaltschmitt, M. 1999. Sustainable crop production: Definition and methodological approach for assessing and implementing sustainability. *Crop Sci.* **39**: 184–193.

Panomataranchagul, M., Sukkasem, C., Peukrai, S., Fullen, M. A., Hocking, T. J. and Mitchell, D. J. 2001. Comparative evaluation of cultural practices to conserve soil and water on highland slopes in Northern Thailand. *In* Helming, K. (ed.) Multidisciplinary Approaches to Soil Conservation Strategies. Zentrum für Agrarlanschafts- und Landnutzungsforschung e.V., Müncheburg, Germany. pp. 147–152.

Pratap, T. and Watson, H. R. 1994. Sloping Agricultural Land Technology (SALT): A Regenerative Option for Sustainable Mountain Farming. International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Pretty, J. N. 1995. Regenerating Agriculture: Policies and Practice for Sustainability and Self-Reliance. Vikas Publishing House Pvt. Ltd., New Delhi, India.

Ravnborg, H. M. 1996. Beyond the farm and within the community: Issues of collective action in participatory natural resource management research. *In* New Frontiers in Participatory Research. International Center for Tropical Agriculture (CIAT), Cali, Columbia. pp. 189–197.

Rigby, D., Woodhouse, P., Young, T. and Burton, M. 2001. Constructing a farm level indicator of sustainable agricultural practice. *Ecol. Econ.* **39**: 463–478.

Ritsema, C. J., Stolte, J., Trouwborst, K., Jetten, V., Ledin, S., Li, R., Liu, B. Y. and Fu, B. J. 2001. An interdisciplinary approach for soil and water conservation planning to improve the sustainability of land use on the Loess Plateau in China. *In* Helming, K. (ed.) Multidisciplinary Approaches to Soil Conservation Strategies. Zentrum für Agrarlanschafts- und Landnutzungsforschung e.V., Müncheburg, Germany. pp. 133–138.

Röling, N. 2005. Gateway to the global garden: Beta/gamma science for dealing with ecological rationality. *In* Pretty, J. (ed.) The Earthscan Reader in Sustainable Agriculture. Earthscan, London. pp. 179–205.

Sajjapongse, A. (ed.). 1992. Technical Report on the Management of Sloping Lands for Sustainable Agriculture in Asia, Phase 1, 1988–1991 (IBSRAM/ASIALAND). International Board for Soil Research and Management (IBSRAM), Bangkok, Thailand.

Shaxson, T. F. 1997. Land quality indicators: Ideas stimulated by work in Costa Rica, North India and Centra Ecuador. *In* Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development. Food and Agriculture Organization (FAO), Rome. Available online at http://www.fao.org/docrep/w4745e/w4745e00.htm (verified on January 12, 2009).

Shi, P. L. and Li, W. H. 1999. Rehabilitation of degraded mountain ecosystems in South Western China: An integrated approach. *Ambio.* **28**(5): 390–397.

Sombatpanit, S. 2001. Thailand's response to land degradation: The need to control soil erosion. *In* Bridges, E. M., Hannam, I. D., Oldeman, L. R., Penning de Vries, F. W. T., Scherr, S. J. and Sombatpanit, S. (eds.) Responses to Land Degradation. Science Publishers Inc., Enfield, USA. pp. 314–324.

Subedi, M., Shrestha, P. K., Sunwar, S. and Subedi, A. 2001. Role of farmers in setting breeding goals. *In* An Exchange of Experiences from South and South-East Asia. Coordination Office, International Center for Tropical Agriculture, Cali, Colombia. pp. 311–318.

Tang, Y. 1999. Factors influencing farmers' adoption of soil conservation programmes in Hindu Kush Himalayan region. *In* McDonald, M. and Brown, K. (eds.) Issues and options in the design of soil and water conservation projects. School of Agriculture and Forest Sciences Publication Number 17. University of Wales, Bangor, UK. pp. 91–102.

Thompson, J. and Pretty, J. N. 1996. Sustainability indicators and soil conservation: A participatory impact study and self-evaluation of the catchment approach of the Ministry of Agriculture, Kenya. *J. Soil Water Conserv.* **51**(4): 265–273.

Tschirley, J. B. 1996. Use of Indicators in Sustainable Agriculture and Rural Development. Sustainable Development Department (SD) Dimensions, Food and Agriculture Organization (FAO), Rome. Available online at http://www.fao.org/sd/EPdirect/EPan0001.htm#topofpage (verified on January 12, 2009).

Tschirley, J. B. 1997. Considerations and constraints on the use of indicators in sustainable agriculture and rural development. *In* Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development. Food and Agriculture Organization (FAO), Rome. Available online at http://www.fao.org/docrep/w4745e/w4745e00.htm (verified on January 12, 2009).

United Nations (UN). 1992. Agenda 21, Programme of Action for Sustainable Development. United Nations (UN) Publications, New York. Available online at http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm (verified on January 12, 2009).

Wattenbach, H. and Friedrich, K. H. 1997. Farming systems indicators for sustainable natural resource management. *In* Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development. Food and Agriculture Organization (FAO), Rome. Available online at http://www.fao.org/docrep/w4745e/w4745e00.htm (verified on January 12, 2009).